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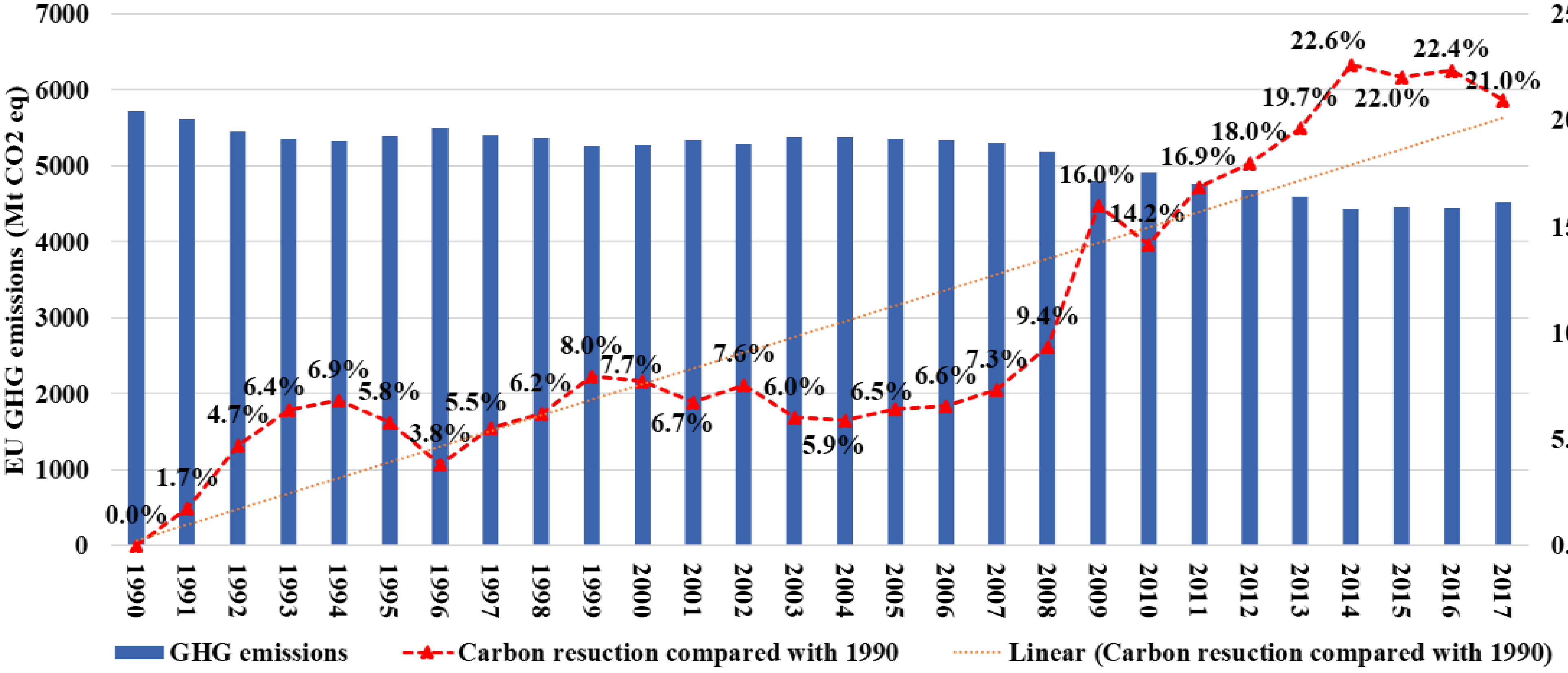
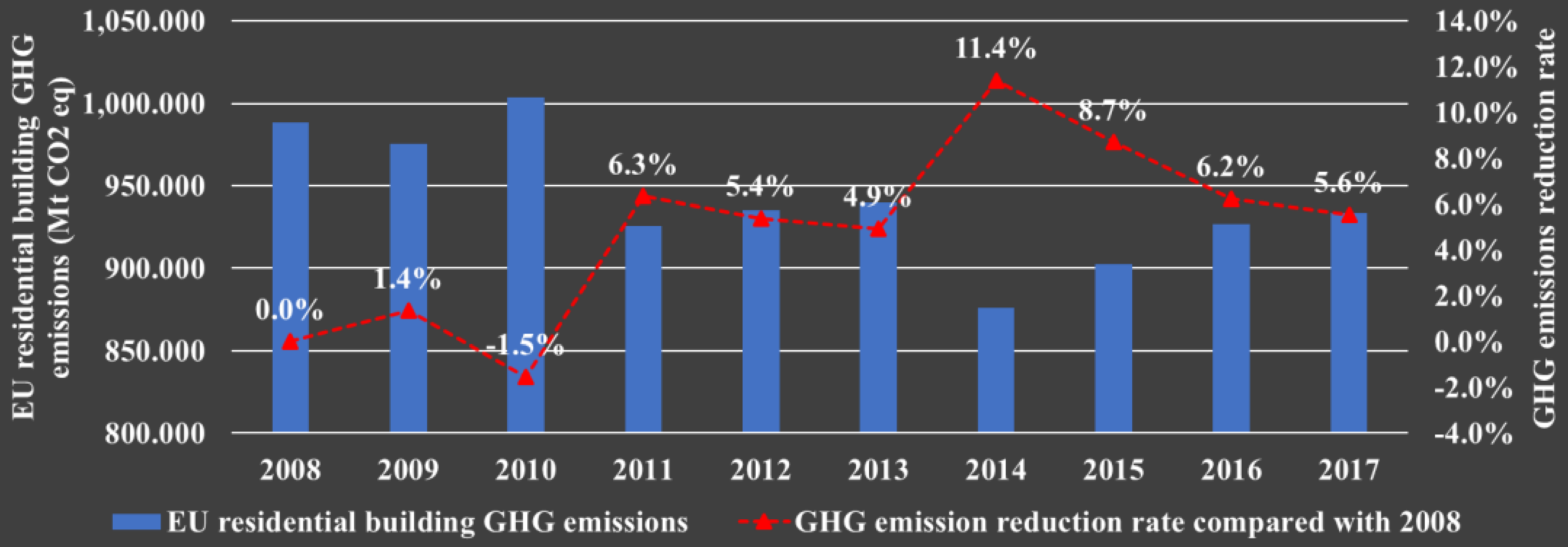
Human-based Inclusive approach for residential building retrofit: review and strategies

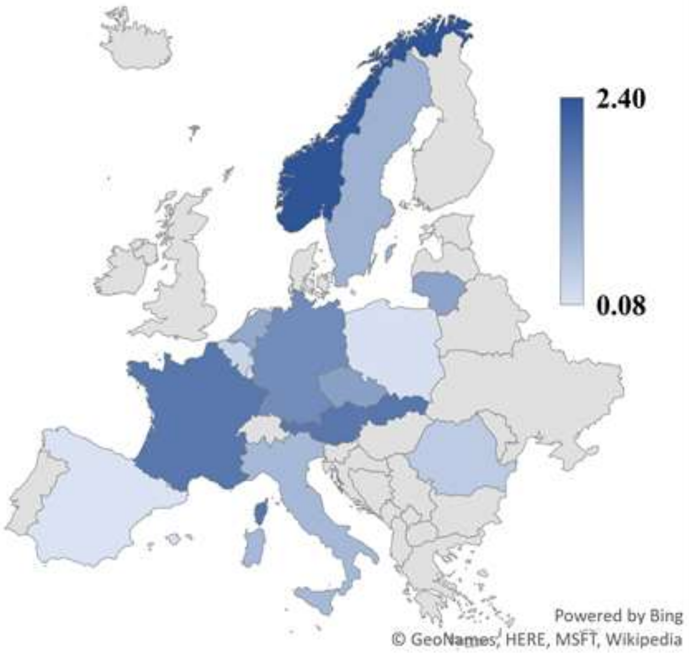
SUSTAINABLE PLACES 2019
June 5-7,2019
Cagliari, Italy

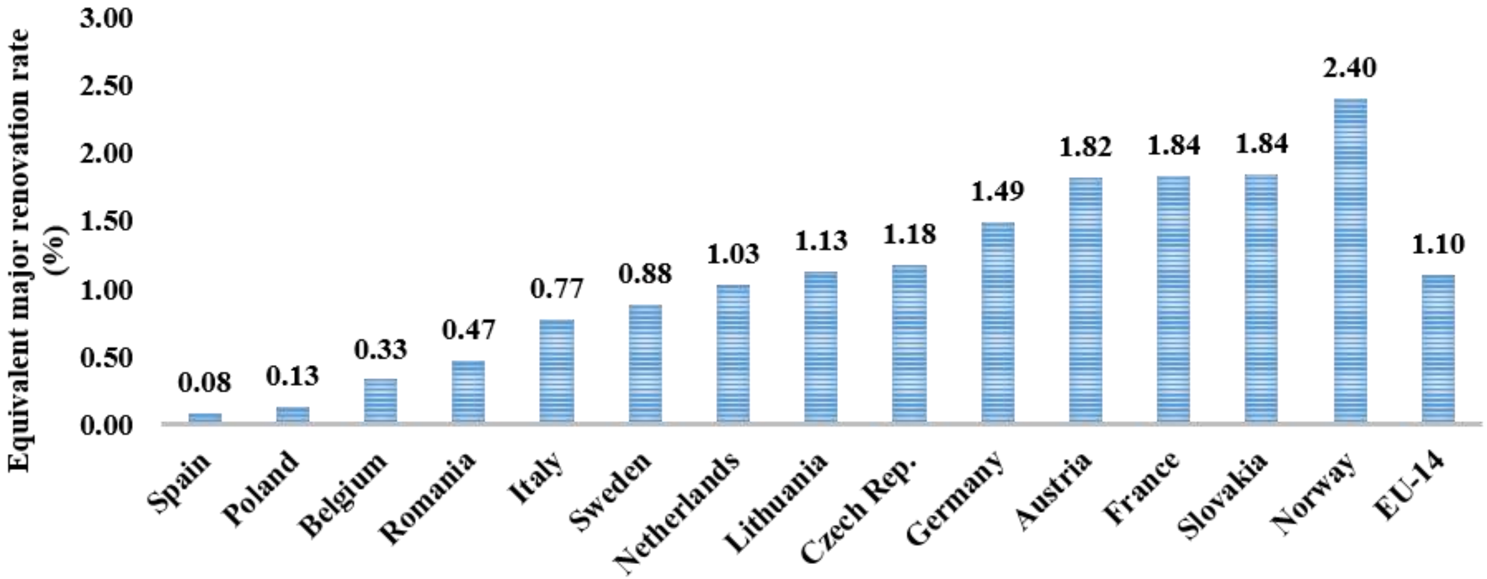


Greenhouse Gas (GHG) emission trend in EU from 1990 to 2017

EU residential building GHG emission and reduction rate from 2008 to 2017







Equivalent major renovation rate in 14 EU countries by the end of 2016

Barriers to residential building retrofit rate

Property features

Non-standard building shape

Restriction to the external wall

Conflict with the surrounding buildings

Householders' preference

Emotional attachment

Householders' value

Pre-existing preference

Installation time

Complicated refurbishment work

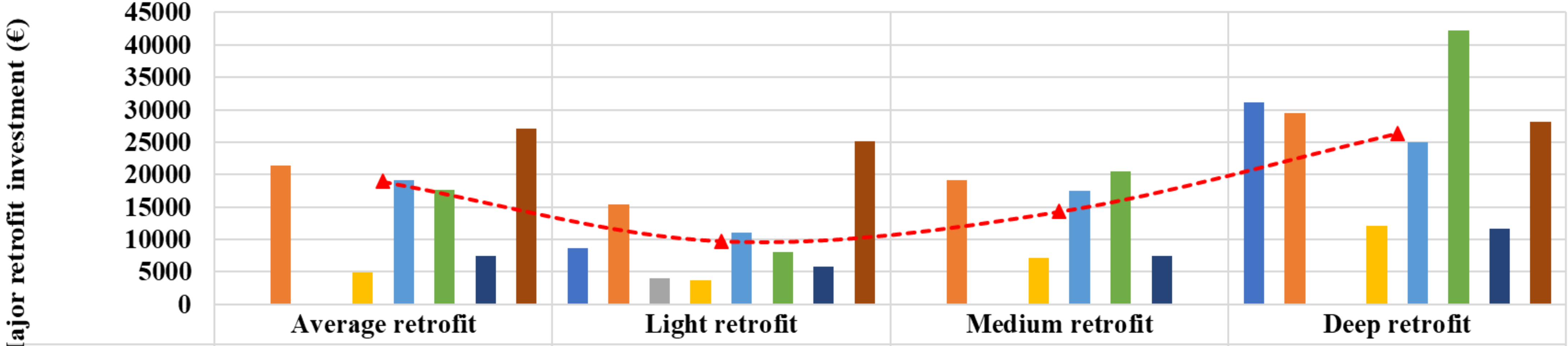
Limited spare time

Inefficient communication

Willingness to pay

Large retrofit expense

Insufficient funding from government



	Average retrofit	Light retrofit	Medium retrofit	Deep retrofit
Italy		8635		31178
Lithuania	21323	15445	19103	29420
Netherlands		3993		
Poland	4941	3771	7215	12025
Czech Rep.	19088	10973	17487	25031
Germany	17679	7989	20532	42188
Romania	7477	5789	7477	11578
Sweden	27044	25057		28113
EU8	18933	9734	14289	26381

Barriers to residential building retrofit rate

Willingness to pay

Motivations for building energy-related retrofit

Improve the indoor comfortable level

Energy saving

Reducing energy bills cost

Improve the value of the properties as financial investment

Government legal regulations for the minimum EPC grades to sale or rent

Influence of peers and the next generation.

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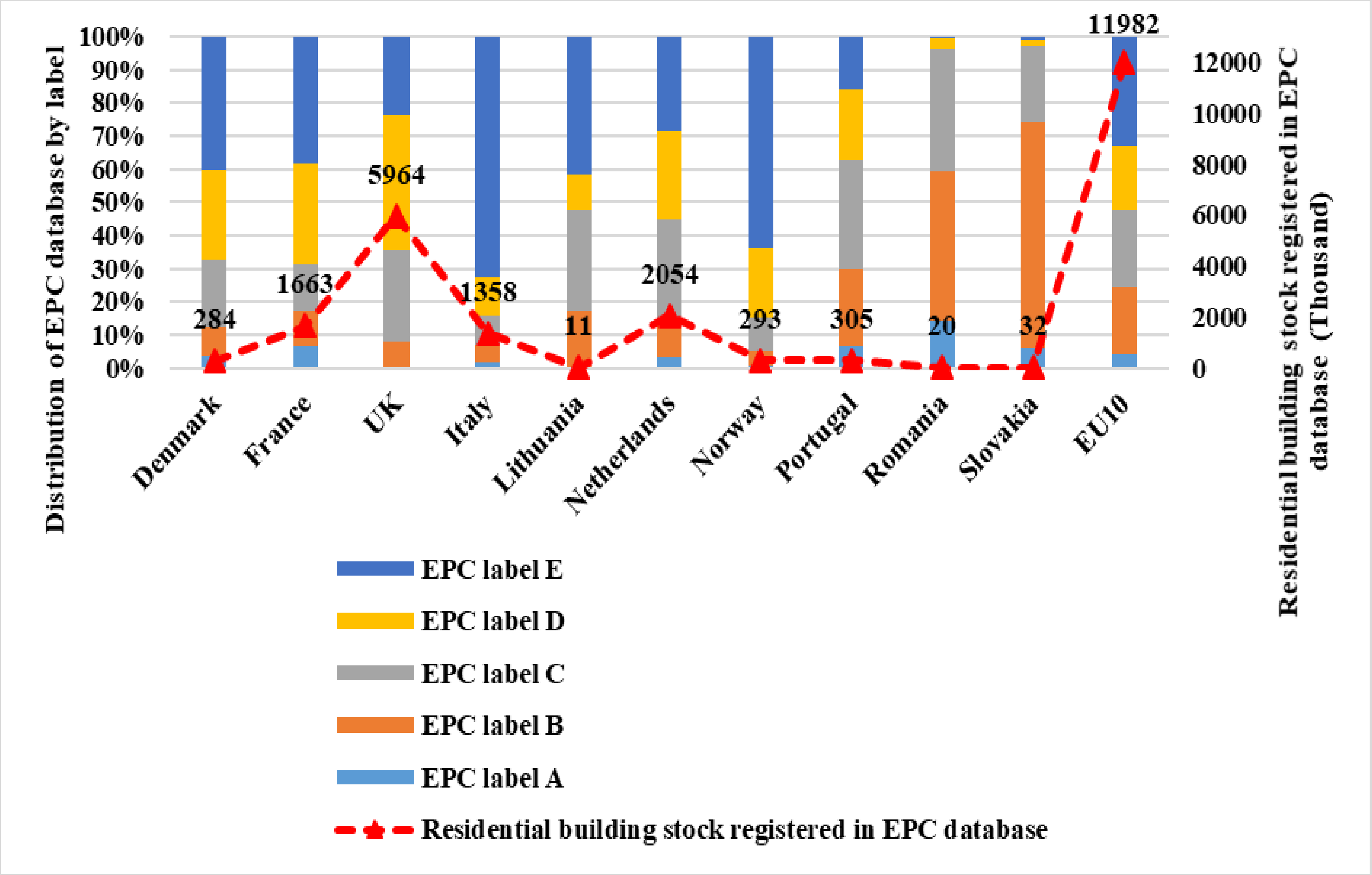
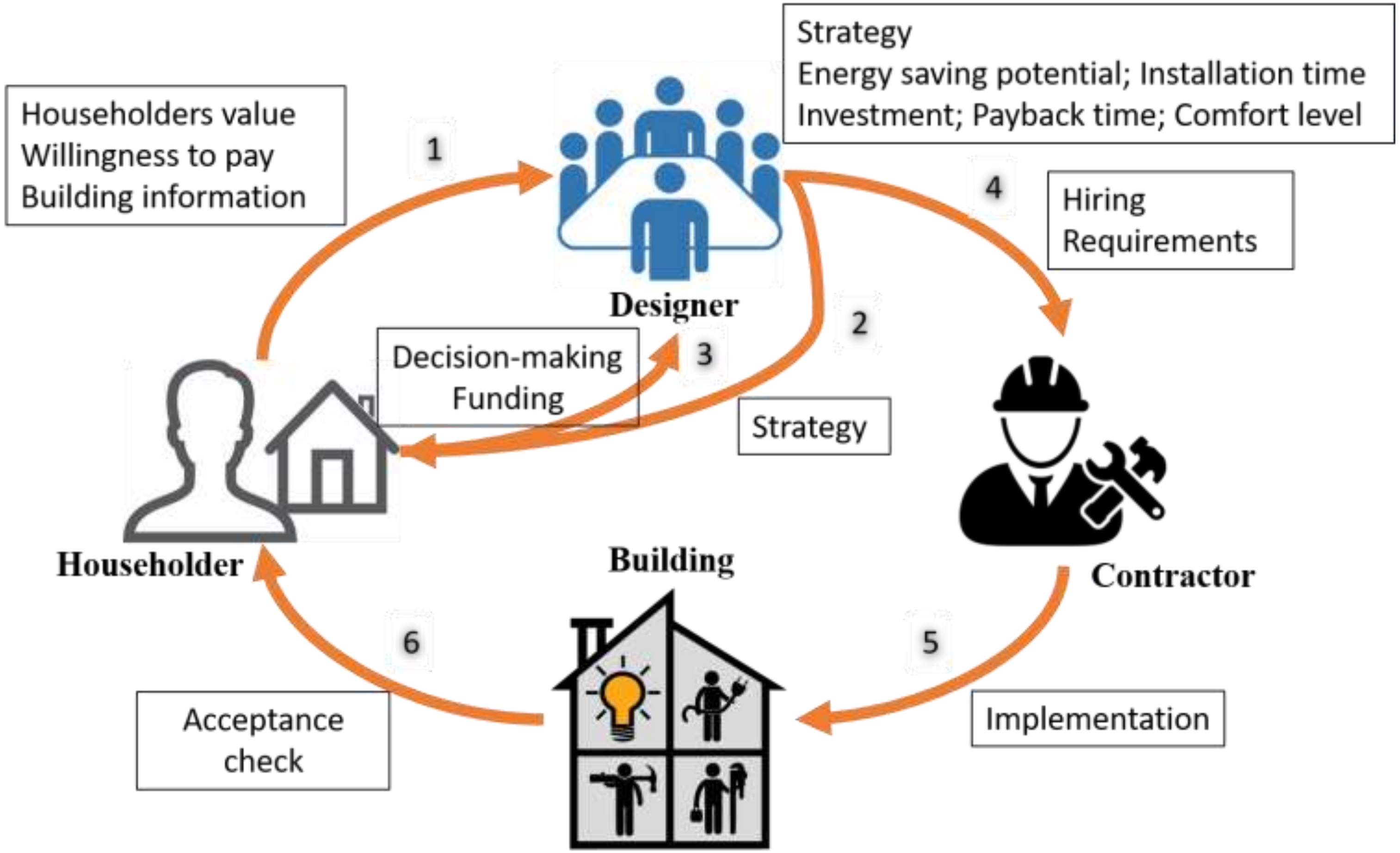
Distribution of EPC building stock by label A-E



Human-based inclusive retrofit (HBIR) approach

- Human-based inclusive retrofit (HBIR) approach to residential buildings means that each individual buildings and its' stakeholder is valued and they are treated with dignity and respect.

Co-operation among householder, designer, contractor, and building



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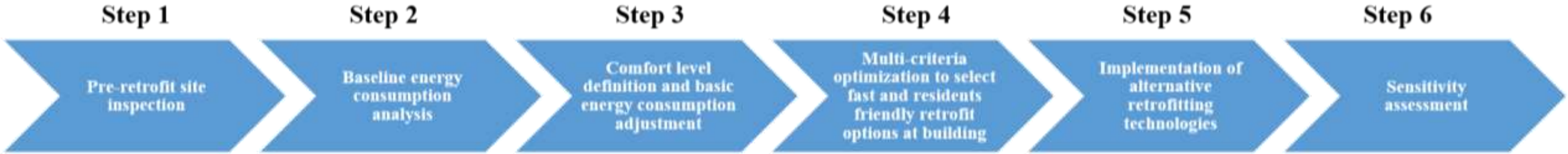
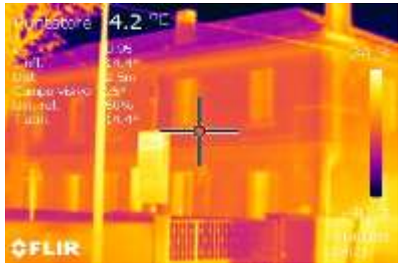
Principles for HBIR approach

- No assumption in the building basic information
- Deep understanding on the motivations/expectations of the householders
- Energy saving strategies and technologies suit with different budgets and preferences
- Bridge the relationship between the retrofit service with the householders to better understand their values and preferences

HBIR approach process

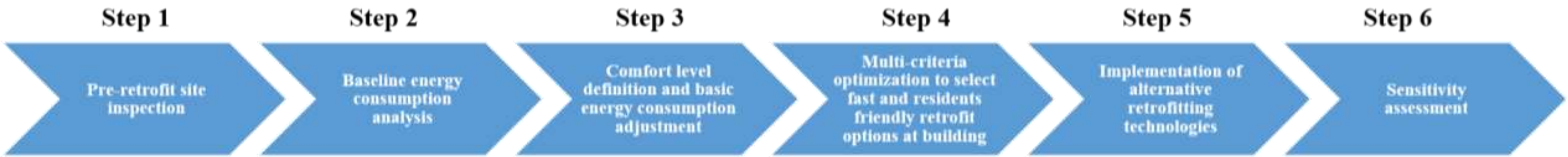


A. Infrared thermograph
B. Rapid in-situ U-value measurement by heat flux method
C. innovative pulse technique
D. human behaviours survey
E. Questionnaires or interviews: motivations and expectations of the householders

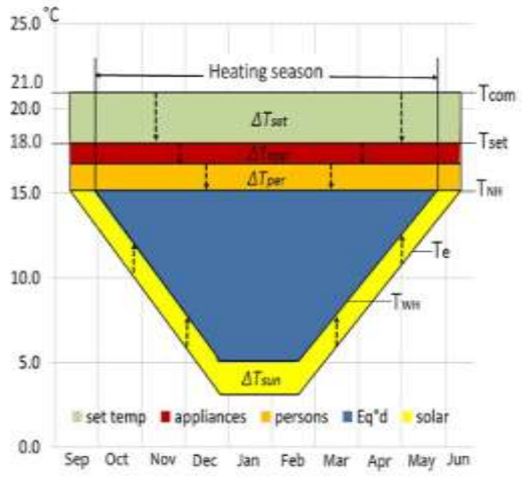


Fast measurements technologies for pre-retrofit site inspection

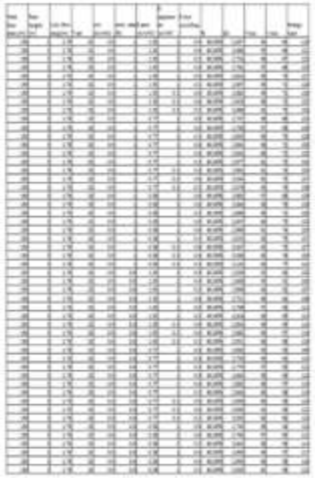
HBIR approach process

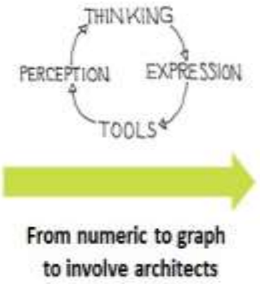


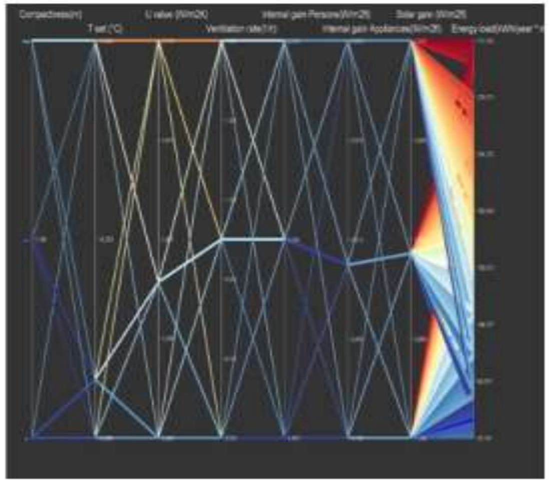
Dynamic EHDD



Process from numerical data to parallel coordinate visualisation







HBIR approach process

Step 1 — Pre-retrofit site inspection

Step 2 — Baseline energy consumption analysis

Step 3 — Comfort level definition and basic energy consumption adjustment

Step 4 — Multi-criteria optimization to select fast and residents friendly retrofit options at building

Step 5 — Implementation of alternative retrofitting technologies

Step 6 — Sensitivity assessment

ESP: Energy saving potential
IT: Retrofit installation time
NPV: Net present value
PBT: Payback time

$$\begin{cases} ESP = \sum_{t=0}^{T}\sum_{i=1}^{n}\sum_{j=1}^{m} S_i^j X_i^j(t) \\ IT = \sum_{i=1}^{n}\sum_{j=1}^{m} T_i^j X_i^j \\ NPV = \sum_{t=1}^{T} \frac{P_{(t)} - M_{(t)}}{(1+d)^t} - \sum_{i=1}^{n}\sum_{j=1}^{m} V_i^j X_i^j(0) \\ PBT = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} V_i^j X_i^j(0)}{\sum_{t=1}^{T}\sum_{i=1}^{n}\sum_{j=1}^{m} S_i^j X_i^j(t) c_i^j / T} \end{cases}$$

$$\min -\mu_1 ESP + \mu_2 IT - \mu_3 NPV + \mu_4 PBT$$

$$\text{s.t.} \begin{cases} \mu_1 + \mu_2 + \mu_3 + \mu_4 = 1 \\ ESP \geq a \\ \sum_{i=1}^{n}\sum_{j=1}^{m} V_i^j X_i^j(0) \leq WTP \\ PBT \leq c \end{cases}$$

$$s_{i+1}^j = f(s_1^j, s_2^j, \cdots s_i^j)$$

$X_i^j(t)$: Alternative interventions (i, j, t), with the jth type alternative retrofit options for the ith type interventions in the t^{th} year, which is simply called alternative (i, j, t).

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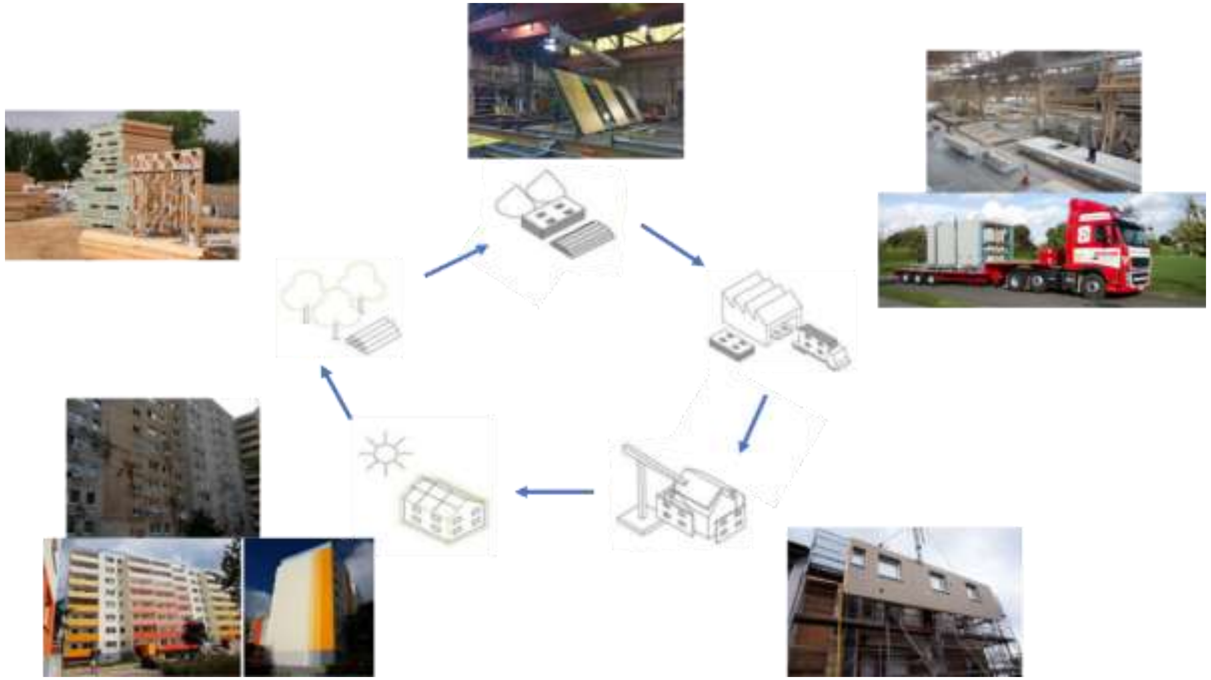
Cycle of 'off-site manufacture & on-site assembly' retrofit implementation



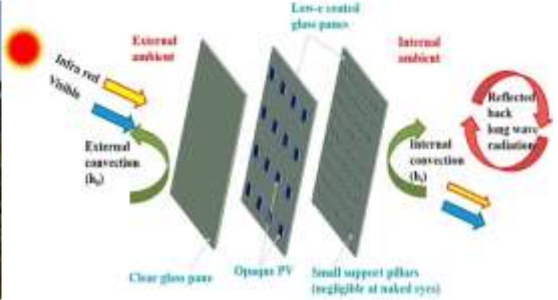
'Future-fit' retrofit technologies

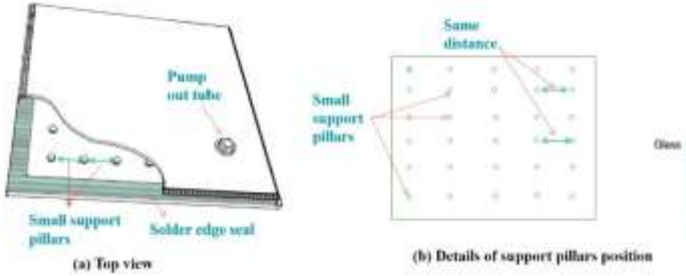
- **Definition:**
  - The 'future-fit' refurbishment technologies are defined as appealing and acceptable technical solutions to householders and neighbours, which is a negotiation between the technical requirements and the expectation of the residents, to not only fulfil the short-term retrofit requirement, but also fit for future further retrofit requirements.
- **Features:**
  - ➢ Appealing and acceptable to householders
  - ➢ Adaptive to existed construction of the property
  - ➢ Available to future extended refurbishment
  - ➢ Maintaining the building characters
  - ➢ Fast installation

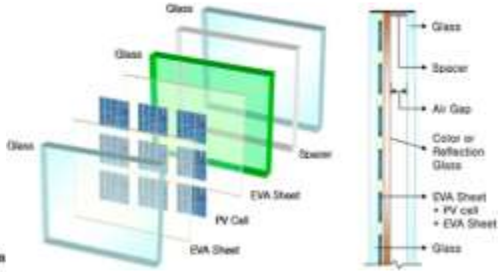
Technologies review

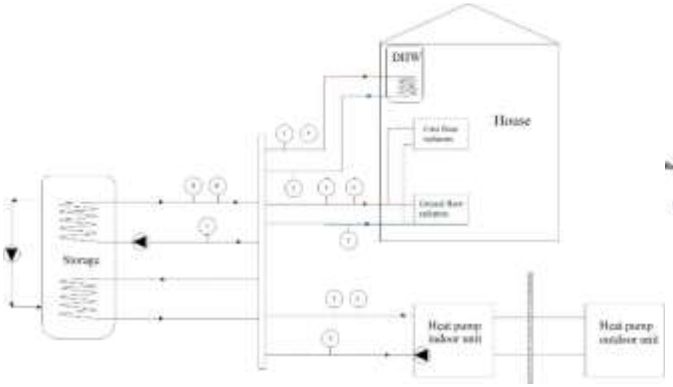
No	Future-fit retrofit technologies	Core materials	Tech Features	Economic level	Installation type
1	Heat insulation solar glazing windows (HISG)	transparent a-Si PV module; nano coating for low reflection; nano TiO2 photocatalyst coating; high reflectivity insulation film	U-value: 1.10 W/m^2·k; Electricity generation efficiency: 7.1% (under solar irradiation of 850W/m2) Self-cleaning coat; thickness:28mm; greatest temperature difference:12.70 °C.	++	Prefabrication
2	Semi-transparent Photovoltaic-vacuum glazing	Cadmium Telluride (CdTe) based PV cells; low-e coating; vacuum glazing	Electricity generation efficiency: 4.3% (under solar irradiation of 1000W/m2); U-value: 0.8 W/m2·k; thickness: 12mm; 33% spectral solar transmittance	++++	Prefabrication
3	Aerogel-enhanced plasterboards	More than 50% vol. sillica aerogel	Thermal conductivity: 0.016 W/m·k Available both interal and external wall	+++	Prefabrication
4	Vacuum insulated panels	Cullulosic nano-crystal (CNC)/Fumed silica porous material	Thermal conductivity: 3.9-4.2 mW/m.K (Fumed silica-VIP); W/m·k,11.7–13.6 mW/m.K (CNC-VIP) Minimum thickness 5mm, service life span 60-160 years	+++++	Prefabrication
5	Biomaterial Interior thermal insulation	Wood fiber board, flax fibers, hemp fibers, jute fibers, and sheep wool	Low thermal conductivity: 0.05 W/m·K, High moisture diffusivity: $1.1 \times 10^{-6} - 1.2 \times 10^{-5}$ m^2/s	+	Modular
8	air-water heat pump	Refrigerant: R410A, heat pump exchanger contacted with air in one side, and water in another side	fixed outlet water temperature of 75 °C, annual system COP with 2.03 (lowest), 2.24 (highest)	++	Modular
9	DX-solar assisted heat pump	Refrigerant: R407C, solar thermal dynamic panels as the evaporator of the heat pump, hot water storage tank	Total surface area of the panel: 4.22 m^2, compressor rated power: 800W, maximum hot water output temperature: 60°C, COP varied from 3.0 to 3.91 under solar radiation varied from 0 to 200 W/ m^2	+++	Modular
10	Ground water-source heat pump	Ground water heat exchanger as the evaporator or condenser of the heat pump	average cooling COP: 3.66 (winter), average heating COP: 4.13 (Summer)	++++	Modular
11	Solar roof tiles	Ergosun Solar roof tiles	Thickness: 4mm Electricity generation efficiency: 15% Different colour options	+++++	Modular/prefabrication

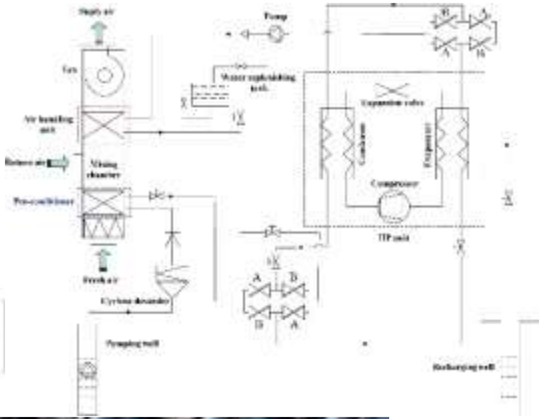
Technologies review



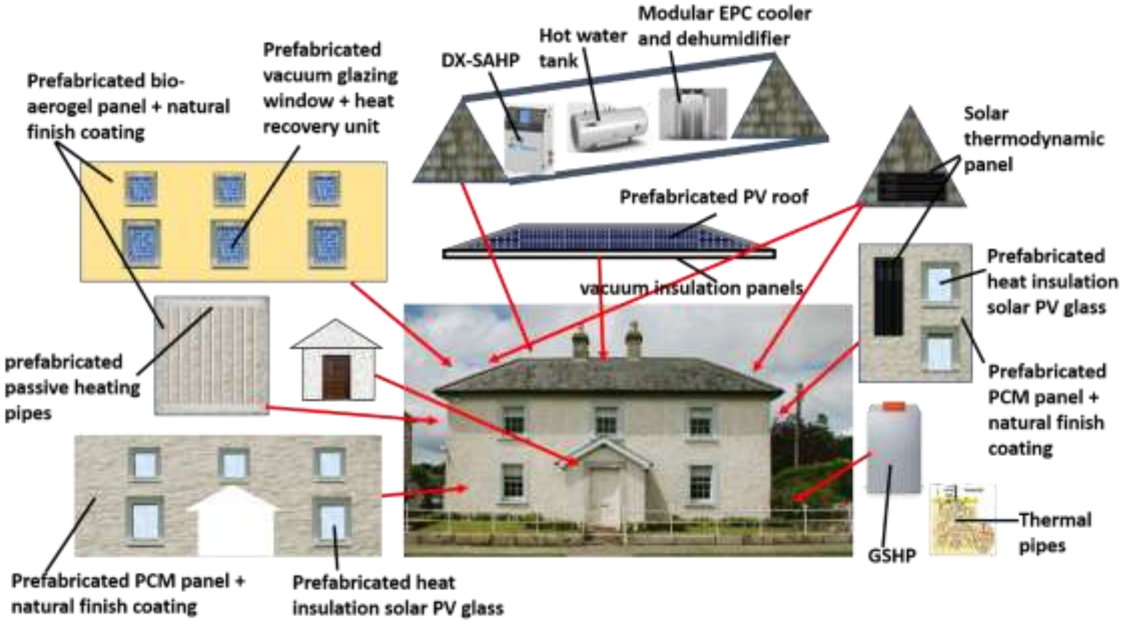


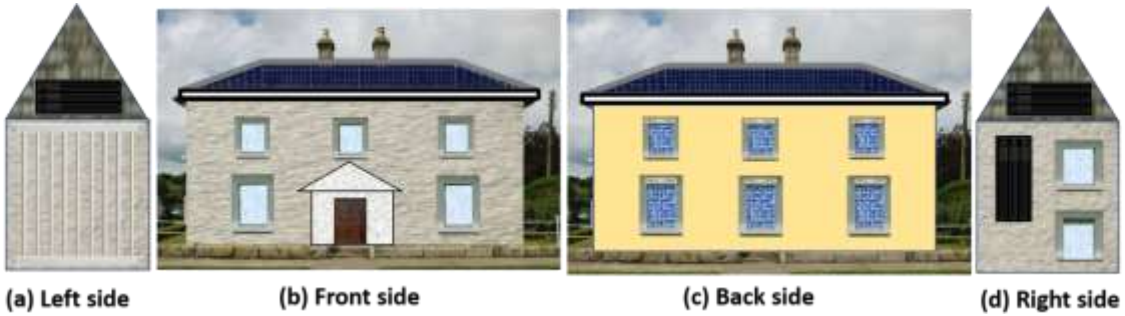






Case study


Modular EPC cooler and dehumidifier
Hot water tank
DX-SAHP
Prefabricated vacuum glazing window + heat recovery unit
Prefabricated bio-aerogel panel + natural finish coating
Solar thermodynamic panel
Prefabricated PV roof
vacuum insulation panels
Prefabricated heat insulation solar PV glass
prefabricated passive heating pipes
Prefabricated PCM panel + natural finish coating
GSHP
Thermal pipes
Prefabricated PCM panel + natural finish coating
Prefabricated heat insulation solar PV glass


(a) Left side
(b) Front side
(c) Back side
(d) Right side

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Thanks!

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